

Advanced Reactor Technologies

California Council on Science and Technology
Sacramento

24 May 2006

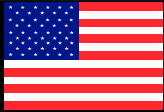








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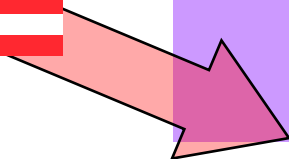
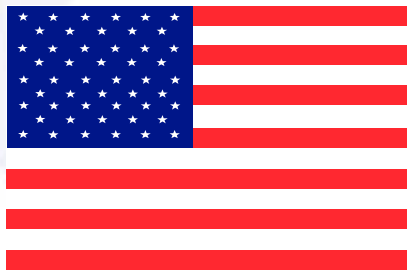
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Vice President / President-Elect
American Nuclear Society

International nuclear electric production











		Number	% CF	% of Total Generation
	United States	103	92	20
	France	59	88	78
	Japan	52	70	25
	Russia	30	68	17
	Canada	21	64	13
	South Korea	20	92	40
	China	9	84	2
	Taiwan	6	88	22
	Mexico	2	79	5

International ranking of nuclear capacity as percentage of total electrical production



Country	% of Nuclear Power to Total Output
Lithuania	80
France	78
Slovakia	57
Belgium	55
Sweden	50
Ukraine	46
South Korea	40
Slovenia	40
Switzerland	40
Bulgaria	38
Armenia	35
Hungary	33
Czech Republic	31
Germany	28
Finland	27
Japan	25
Spain	24
U.K.	24
Taiwan	22
U.S.A.	20

Current unit expansion in Asia/Europe

	Country	Operating Units	Number of Units Under Construction	Near-Term Plan (GWe)	By (year)
	India	14	8	29.5	2022
	South Korea	20	6	26.6	2015
	Russia	30	4	40	2020
	Japan	52	3	15	2025
	China	9	2	40	2020
	Ukraine	8	2	22	2030
	Pakistan	2	—	8.5	2030
	Iran	0	1	—	—
	Romania	1	1	—	—
	Finland	4	1 ²⁸	— ¹⁶⁰	—

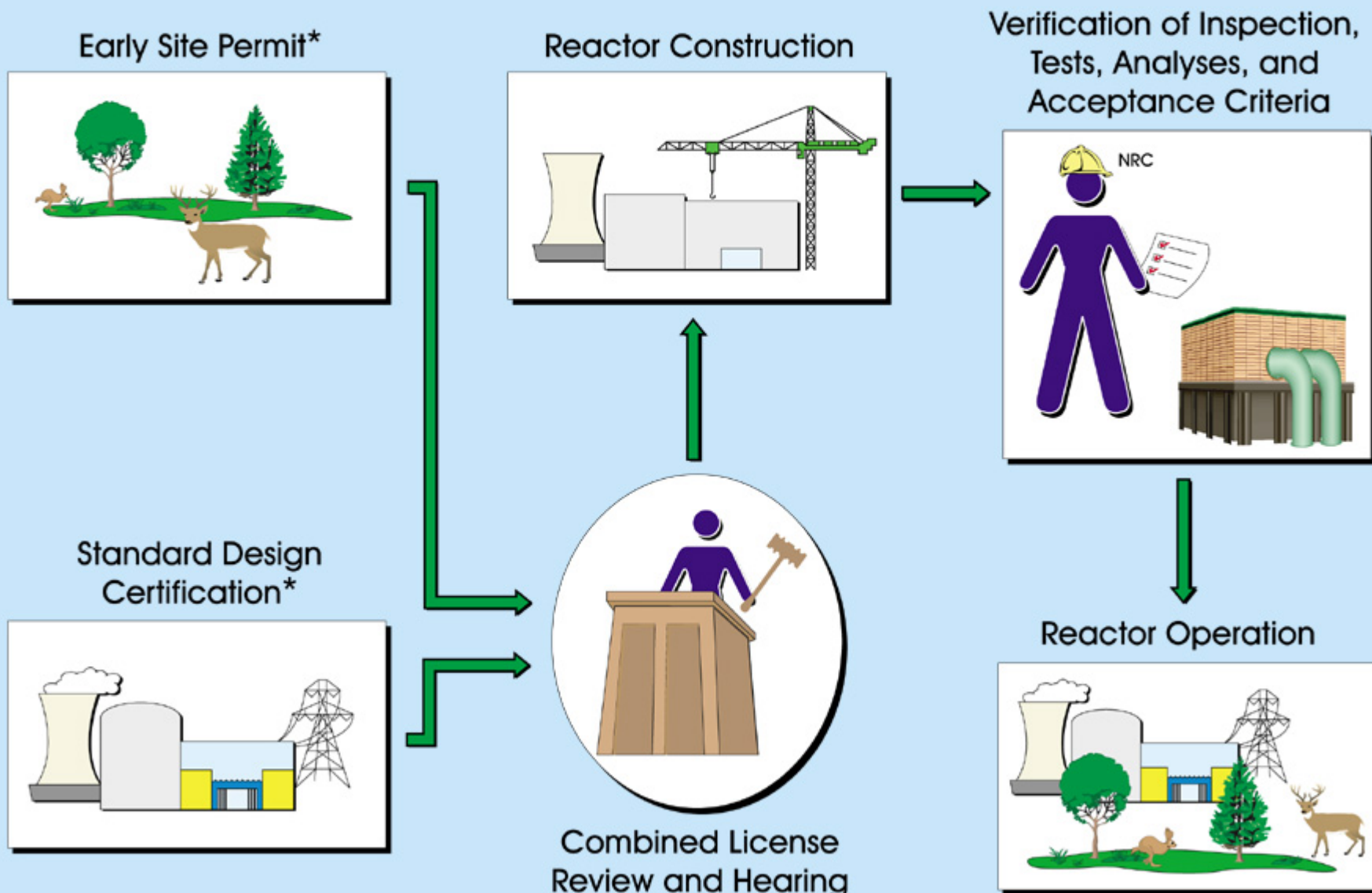




The Energy Policy Act of 2005

- Includes incentives for new nuclear plants
- Industry has responded with expressions of interest in 17 new nuclear reactors

Combined Licenses, Early Site Permits, and Standard Design Certifications



* or equivalent process

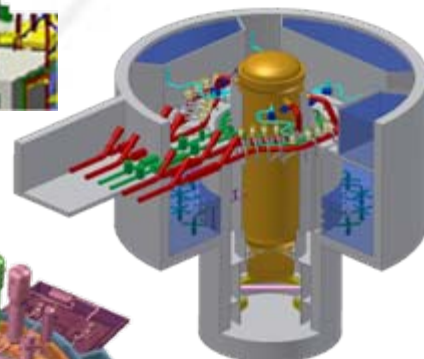
New designs available today—*Generation III+*

Advanced Light Water Reactors (ALWRs)

- Standardized designs based on modularization producing shorter construction schedules
- Passive or redundant systems to enhance safety
- Easier to protect from terrorist attacks

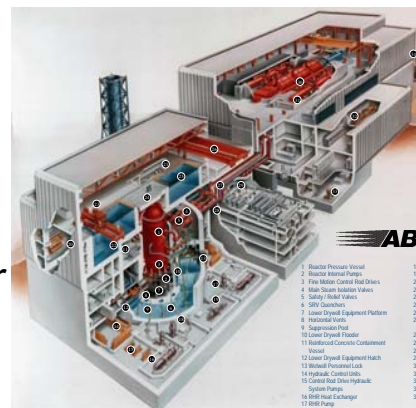


Gen-III+



further evolution

Gen-III

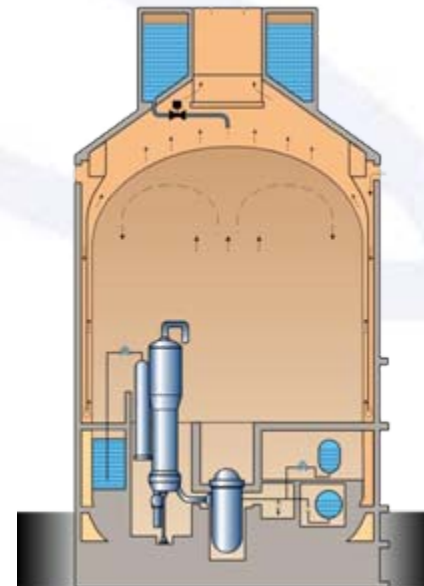


ABWR

- 1 Reactor Pressure Vessel
- 2 Reactor Internal Piping
- 3 Fuel Element Control Rod Drive
- 4 Main Steam Generator
- 5 Safety Relief Valve
- 6 SIV Control
- 7 Lower Drywell Equipment Platform
- 8 Horizontal Vents
- 9 Horizontal Vents
- 10 Lower Drywell Reactor
- 11 Horizontal Vents
- 12 Lower Drywell Equipment Platform
- 13 Wetwell Pressure Lock
- 14 Wetwell Pressure Lock
- 15 Control Rod Drive Hydraulic System
- 16 Wetwell Pressure Lock
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- 34 Wetwell Pressure Lock

Westinghouse

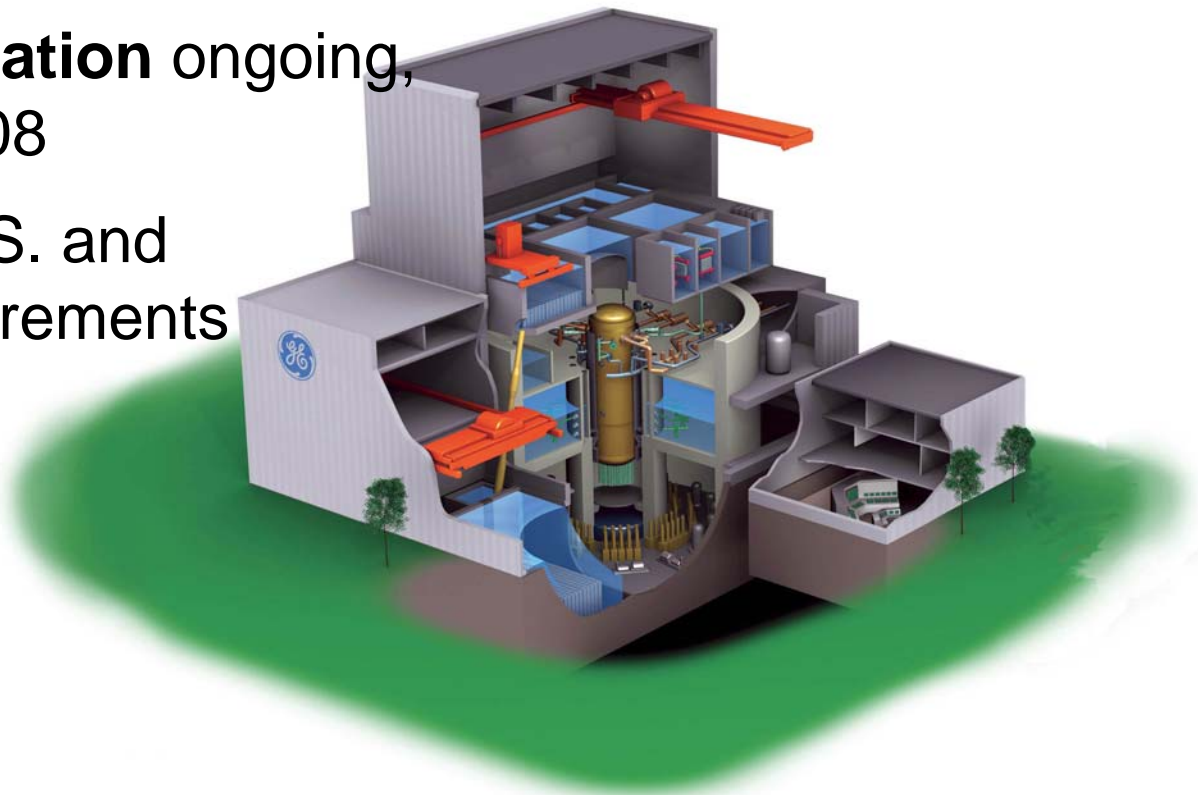
- **AP 1000
(1,148 MWe)**
 - Passive safety systems
 - **NRC design certification** provides regulatory certainty:
 - AP 600—Approved December 1999
 - AP 1000—Approved early 2006



General Electric

- **Economic Simplified Boiling Water Reactor ESBWR (1,550 MWe)**

- Passive safety systems
- **Design certification** ongoing, expected in 2008
- Designed to U.S. and European requirements

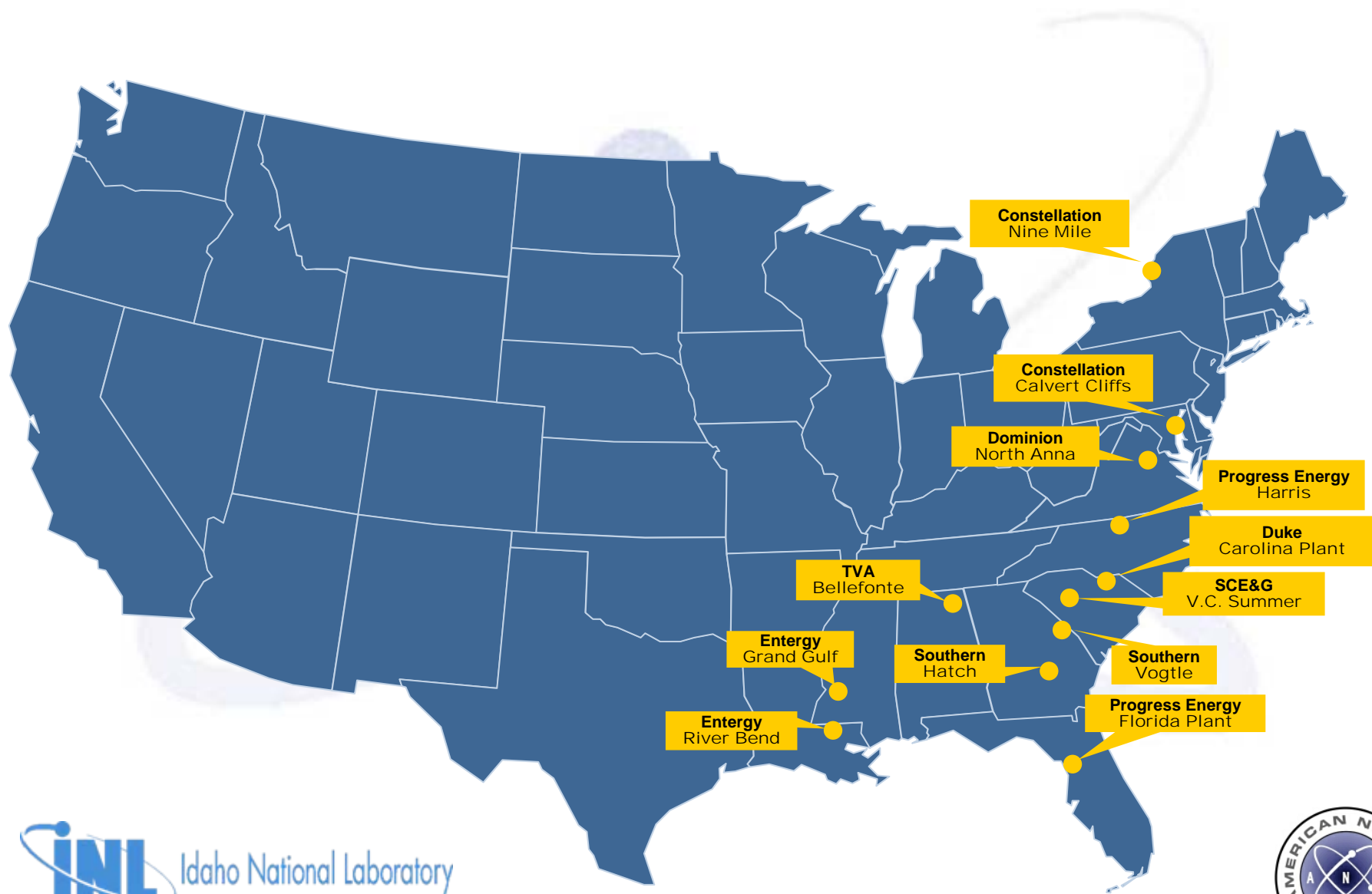


AREVA/Framatome ANP

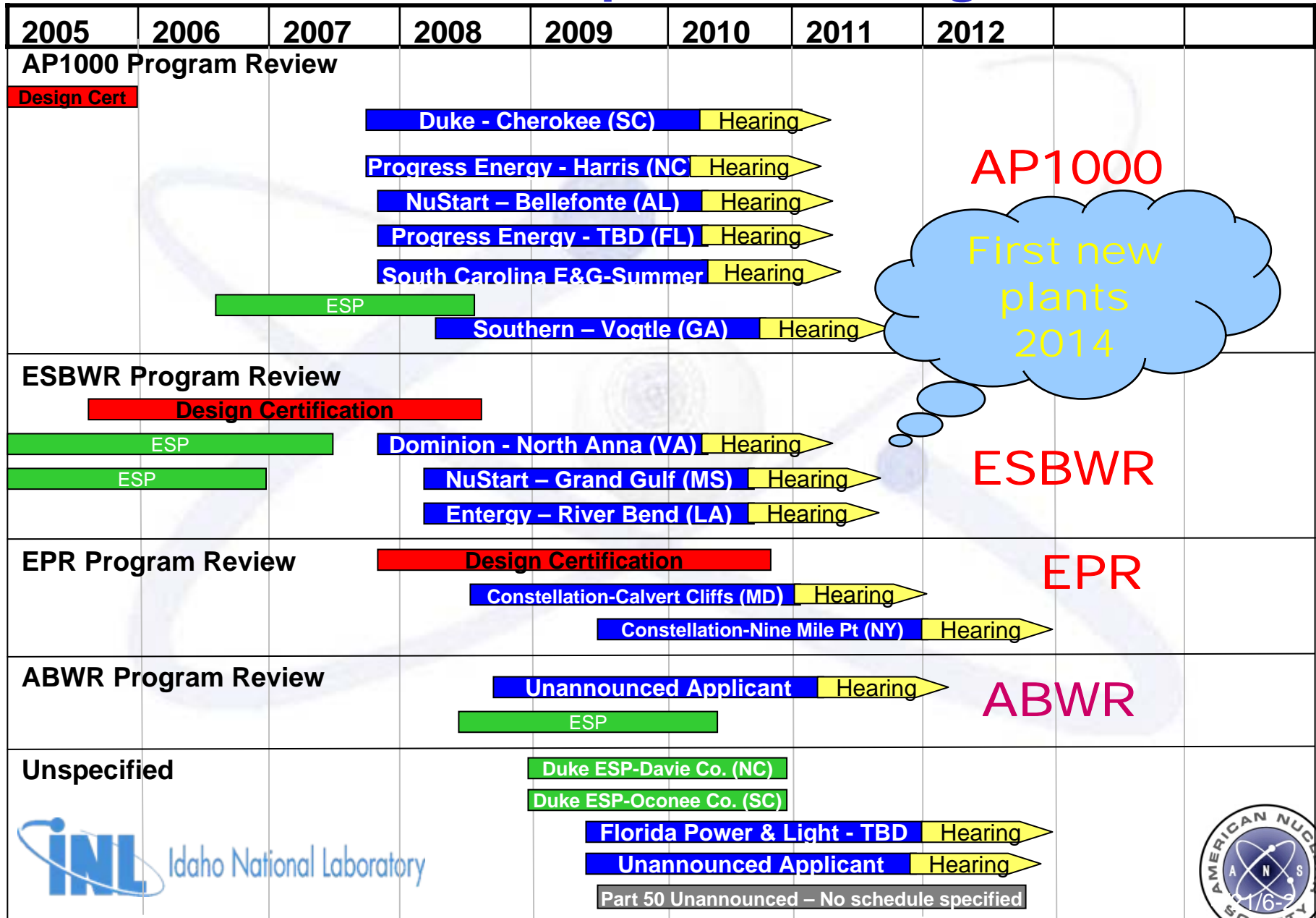
- **Evolutionary Power Reactor EPR (1,600 MWe)**
 - Redundant safety systems
 - Preparing for certification
 - European version under construction in Finland
 - **Design certification** review to start in 2007; completion estimated in 2010



First movers for new nuclear plants



NRC's estimate of new plant licensing schedule

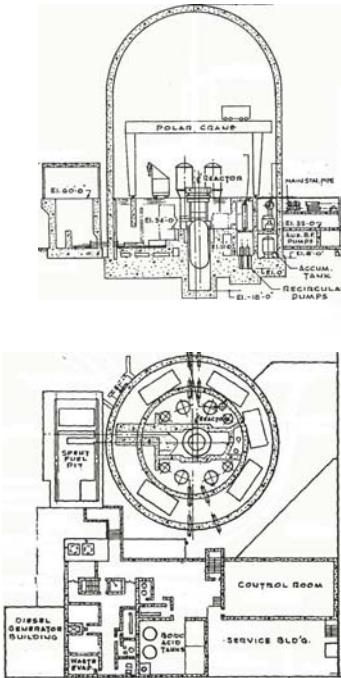


The new ALWR designs reverse the trend of increasing steel and concrete

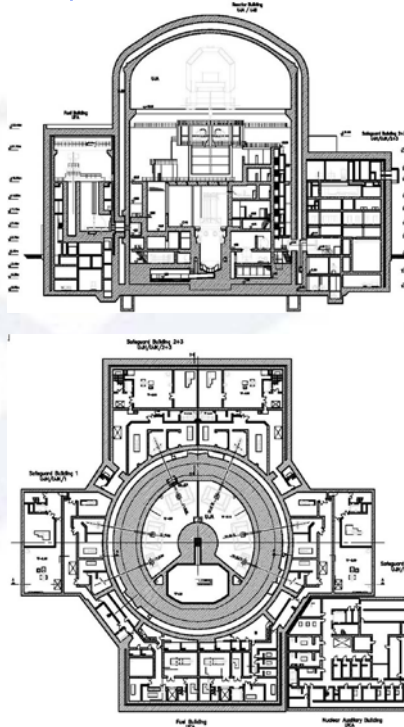
Gen II

Gen III - Active

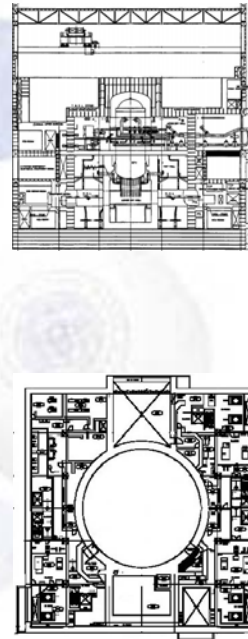
Gen III+ - Passive



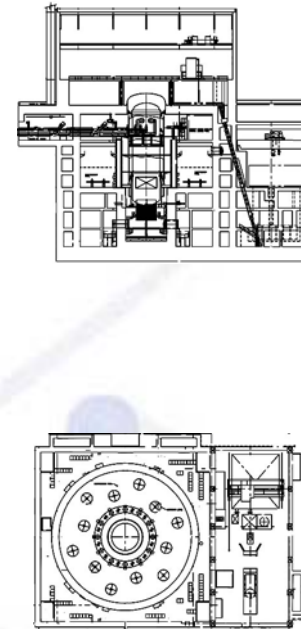
1970's PWR
1000 MWe
40 MT_{steel}/MW



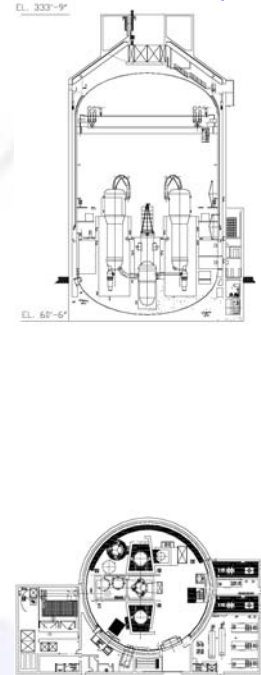
EPR
1600 MWe
49 MT_{steel}/MW



ABWR
1380 MWe
51 MT_{steel}/MW



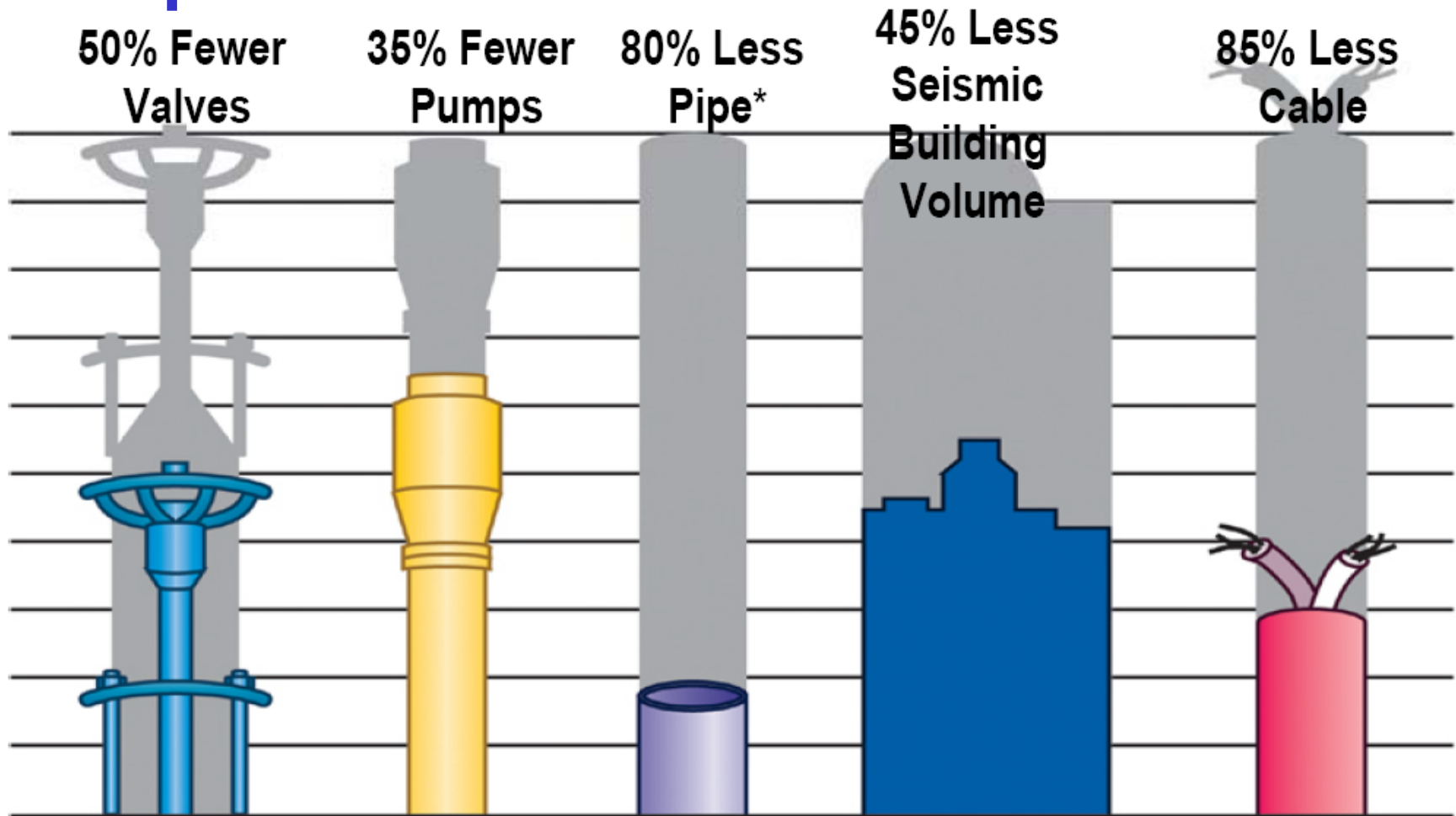
ESBWR
1550 MWe
— MT_{steel}/MW



AP-1000
1090MWe
42 MT_{steel}/MW

Scaled Comparison

AP-1000 has large reduction in components





Generation IV Initiative – Mission

♦ International initiative under DOE leadership

- DOE and other countries to plan next-generation nuclear technology R&D collectively.
- Governed by Gen IV International Forum (GIF)

♦ Vision

- Develop advanced nuclear technologies for deployment by 2030 in collaboration with GIF partners

♦ Forward-looking technology goals established

- Economics, safety, waste/sustainability, proliferation resistance and physical protection

♦ Gen IV Roadmap

- Identified fuel cycles and reactors to advance goals and serve future energy markets

♦ GIF selected 6 concepts as most-promising

GFR -- Gas-cooled fast reactor

LFR -- Lead-cooled fast reactor

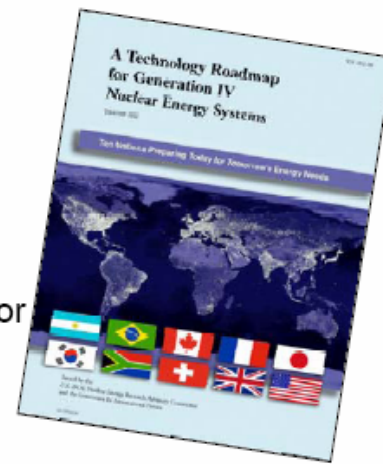
VHTR -- Very high temperature reactor

SFR -- Sodium-cooled fast reactor

SCWR -- Supercritical water-cooled reactor

MSR -- Molten salt reactor

♦ U.S. now focused on Very-High-Temperature Reactor (VHTR) and Sodium Fast Reactor (SFR)

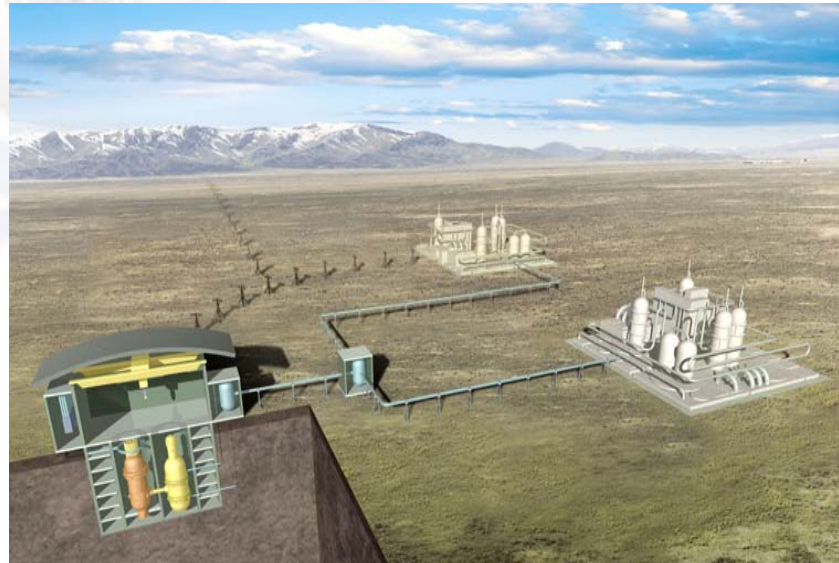
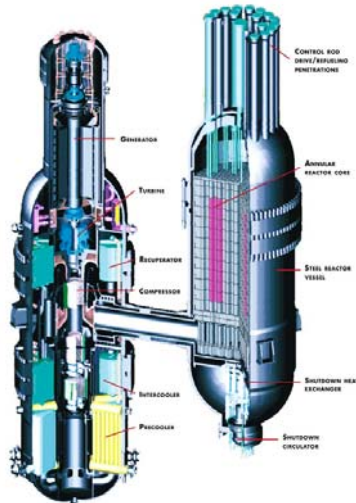


High-temperature Gen IV reactors may have multiple applications

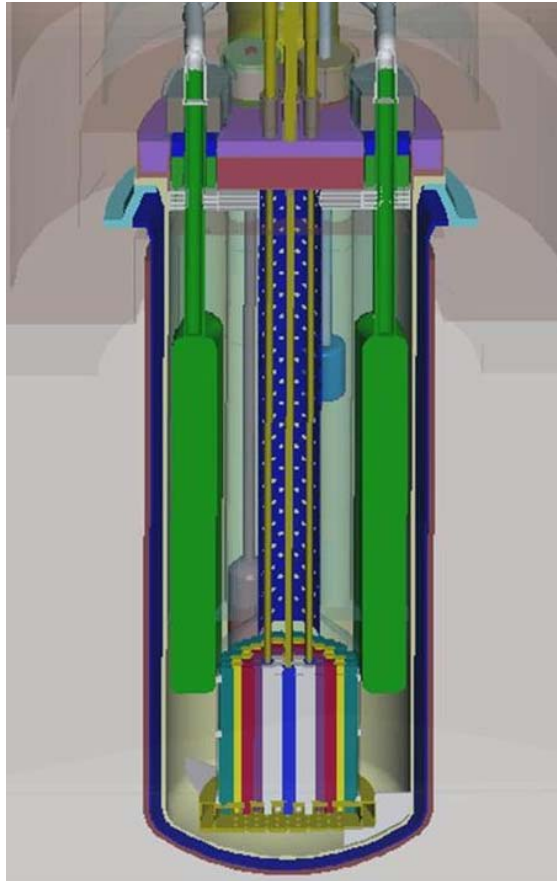


- NGNP technology not fixed until 2011
- Strategy due to Congress 8/8/08
- Idaho National Laboratory to provide support
- Flexible licensing strategy

GT-MHR
286 MWe



Sodium fast reactor development targets spent fuel management



R & D Objectives

- 200-MWt demonstration burner
- Cost reduction design features
- Co-located with processing facility
- Fuels and safety testing capability

Demonstration Focus Areas

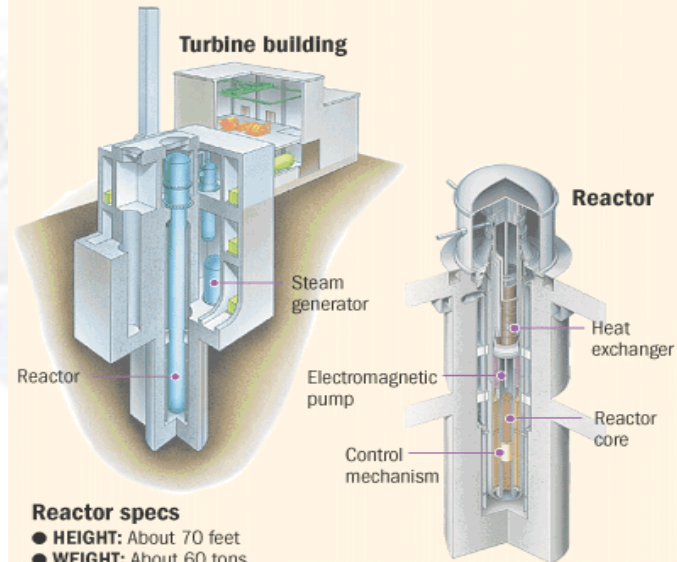
- Prototypical recycled fuel
- Verification of safety performance
- Remote handling refueling equipment
- Economics for deployed power reactors

Toshiba 4S sodium cooled reactor targets small niche markets

- **10 MWe**
- Designed for remote locations without much infrastructure
- **No refueling over 30 year lifetime**
- Reactivity control – movable reflectors
- Passive safety
- **NRC pre-application review pending**
- Galena, Alaska?

Nuclear power for rural villages

Toshiba is proposing a small modular nuclear reactor to supply power for Galena, a Yukon River town of 713. It has yet to be constructed, but would likely consist of a 70-foot tube with a garbage-can-sized uranium core at the bottom and a liquid metal heat exchanger in the upper section. The assembly would be buried in a concrete silo. The slow-burning uranium would last 30 years, powering steam turbines to create electricity. Conceptual drawings of the plant are below.



Reactor specs

- **HEIGHT:** About 70 feet
- **WEIGHT:** About 60 tons
- **ELECTRICAL PRODUCTION:** About 10 megawatts. A typical Lower 48 nuclear plant is 1,000 megawatts or more. When the fuel is spent, the core can be removed and recycled.
- **ELECTRICAL COST:** The plant could generate electricity at 10 cents a kilowatt hour, which is slightly more than in Anchorage or Fairbanks, but a half to two-thirds the current cost in Galena.
- **CONSTRUCTION:** The modular plant is constructed in a factory and could be delivered by barge to the site. Components are small enough to be delivered by truck or helicopter.
- **PROJECT COST:** \$20 million. Toshiba says it will install the Galena reactor free, as a demonstration project.
- **NUMBER OF EMPLOYEES:** The reactor has no operator or maintenance personnel; the steam generator would probably require the same number of people as the diesel-powered plants.

[Westinghouse] International Reactor Innovative and Secure (IRIS)

- Integral LWR (335 MWe)
- Safety by innovative design features and passive safety systems
- 3 - 4 year core
- Modular fabrication and construction
- Spherical Containment
- Generation IV Objectives
 - Proliferation Resistance
 - Enhanced Safety
 - Improved Economics
 - Reduced Waste
- **NRC pre-application review underway**

